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Infectious pestivirus pseudo-particles containing functional Erns, E1, E2 envelope proteins

The invention relates to the generation and the use of pestivirus pseudo-particles containing native functional E1, E2 envelope glycoproteins assembled onto retroviral core particles. These particles are highly infectious and constitute a valid model of pestivirus virion.

Pestivirus are single-stranded RNA (ssRNA) enveloped spherical viruses that constitute a genus within the family Flaviviridae, which also includes the genera flavivirus and hepacivirus (human hepatitis C viruses). Several pestiviruses are important mammalian pathogens, especially cattlepathogens, such as the bovine viral diarrhea, the swine fever and the border disease viruses. Pestivirus can cause mucosal diseases (diarrhea), respiratory disease, suppression of an animal's immune system, and severe bleeding disorders.

Pestivirus structural proteins and non structural proteins are expressed from a single polyprotein precursor and individually released in their respective cell compartments upon cleavage by cellular and viral proteases. By analogy with other members of the Flaviviridae, pestivirus genomic organization suggests a virus consisting of a nucleocapsid comprising a viral genome and core protein (C) coated by a lipid envelop containing the two envelope glycoproteins E1 and E2.

The majority of acute bovine viral diarrhea virus (BVDV) infections are caused by noncytopathic viruses. Cattle acutely or persistently infected with BVDV are the primary source of virus. Infected animals shed virus in nasal and oral secretions, feces and urine. The primary virus entrance route is probably oral nasally. Other less important routes of entry may include infected semen, biting insects, and contaminated instruments. Following entry and contact with the mucosal lining of the mouth or nose, initial replication occurs in epithelial cells with a predilection for the palatine tonsils. From here, the virus is able to spread systemically through the blood stream. Spread can occur through both free virus in the serum and virus infected leucocytes, particularly lymphocytes and monocytes. Isolation of virus from serum or leucocytes is generally possible between 3 and 10 days post infection. During systemic spread, the virus is able to gain entry to most tissues with a preference for lymphoid tissues. BVDV broadly infects cattle, sheep, goats, and pigs.

Classical swine fever disease (SVF, previously called hog cholera virus) is another member of the family Flaviviridae, genus Pestivirus. SFV is an economically important contagious disease of swine world-wide. The disease occurs in much of Asia, Central and South America, and parts of Europe and Africa. Several countries have eradication programs in force, based on rapid diagnosis and stamping out of infected herds, supplemented by other control measures. Despite these efforts, SFV has still not been eliminated in many countries. Although SFV can replicate in non-porcine cells, porcine kidney cells are used most frequently for virus growth. Virus replication is restricted to the cytoplasm of the cell and does not result in a cytopathic effect. The first progeny virus is released from the cells at 5-6 hours post-infection. Virion assembly occurs on membranes of the endoplasmic reticulum, but performed capsids and budding are not seen. Instead, fully formed virions appear within the cisternae of the endoplasmic reticulum and are released via exocytosis or cell lysis. Pigs and wild boar are the natural hosts of SFV.

Border disease (BD) is a congenital disease of sheep that was first reported in the bordering countries of England and Wales. A similar, but rare condition also occurs in goats. The causative agent of BD, the border disease virus (BDV), is found worldwide in sheep. Five to fifty percent of sheep tested have antibodies against BD virus; meaning that these ewes have either been exposed to, or are carrying the disease. Transmission of the virus occurs via oral and/or intranasal routes in sheep. Persistently infected sheep are the primary virus reservoir. These ewes will shed virus in all excretions and secretions. Lambs of persistently infected ewes are at risk of becoming persistently infected with the BDV, and thereby perpetuating the disease cycle.

The invention describes the formation and use of infectious pestivirus pseudo-particles harboring unmodified E1 and E2 glycoproteins.

Definitions

The terms "*vector*", "*cloning vector*" and "*expression vector*" mean the vehicle by which a DNA or RNA sequence (e.g. a foreign gene) can be introduced into a host cell, so as to transform the host and promote expression (e.g. transcription and translation) of the introduced sequence. Vectors typically comprise the DNA of a transmissible agent, into which foreign DNA is inserted. A common way to insert one segment of DNA into another segment of DNA involves the use of enzymes called

restriction enzymes that cleave DNA at specific sites (specific groups of nucleotides) called restriction sites. Generally, foreign DNA is inserted at one or more restriction sites of the vector DNA, and then is carried by the vector into a host cell along with the transmissible vector DNA. A segment or sequence of DNA having inserted or added DNA, such as an expression vector, can also be called a "*DNA construct*". A common type of vector is a "*plasmid*", which generally is a self-contained molecule of double-stranded DNA, usually of bacterial origin, that can readily accept additional (foreign).DNA and which can readily be introduced into a suitable host cell. A plasmid vector often contains coding DNA and promoter DNA and has one or more restriction sites suitable for inserting foreign DNA. Coding DNA is a DNA sequence that encodes a particular amino acid sequence for a particular protein or enzyme. Promoter DNA is a DNA sequence that initiates, regulates, or otherwise mediates or controls the expression of the coding DNA. Promoter DNA and coding DNA may be from the same gene or from different genes, and may be from the same or different organisms. A large number of vectors, including plasmid and fungal vectors, have been described for replication and/or expression in a variety of eukaryotic and prokaryotic hosts.

A "*coding sequence*" or a sequence "*encoding*" an expression product, such as a RNA, polypeptide, protein, or enzyme, is a nucleotide sequence that, when expressed, results in the production of that RNA, polypeptide, protein, or enzyme, i.e., the nucleotide sequence encodes an amino acid sequence for that polypeptide, protein or enzyme.

The term "*transfection*" means the introduction of a foreign nucleic acid (DNA, cDNA or RNA) into a cell so that the host cell will express the introduced gene or sequence to produce a desired substance, typically a protein coded by the introduced gene or sequence. The introduced gene may include regulatory or control sequences, such as start, stop, promoter, signal, secretion, or other sequences used by a cell's genetic machinery. A host cell that receives and expresses introduced DNA or RNA has been "*transformed*".

The term "*host cell*" means any cell of any organism that is selected, modified, transformed, grown, or used or manipulated in any way, for the production of a substance by the cell, for example the expression by the cell of a gene, a DNA sequence, a protein, a virion. In the context of the invention, the host cell is a mammalian cell, preferably a cell from cattle, rabbit, pig, goat, swine. Suitable host

cells include for instance epithelial cells, leucocytes, lymphocytes, macrophages, monocytes, primary kidney cells from cattle or pig, and BT cells (ATCC CRL-1390).

As used herein, the term "*permissive cell*" is meant for a cell that is permissive for a pestivirus infection.

"*Pestiviruses*" are members of the *Flaviviridae* family. Pestivirus genome encodes a single polyprotein NH_2-C-Erns-E1-E2-p7-NS2-NS3-NS4a-NS4b-NS5a-NS5b-COOH that is processed co and post-translationally into both structural (N-terminal nucleocapsid protein termed "Core" (C), and proteins Erns, E1 and E2) and non-structural (NS) proteins. The amino-terminal part of the polyprotein is cleaved by host cell proteases and its products, core and envelope (Erns, E1 and E2) proteins, are believed to be the major constituents of pestivirus particles (virions). However, the ectodomain Erns-E1 is thought to be processed upon synthesis, thus releasing the non anchored Erns protein.

Although most cleavages in the polyprotein precursor proceed to completion during or immediately after translation, processing between E2 and p7, a hydrophobic domain found at the carboxy terminus of E2, is incomplete and results in the production of fully processed E2 and uncleaved E2-p7.

In the context of the invention, said pestivitus may be of any specie, genotype, subtype, or variant of perstivirus strains. Preferably, the pestivirus according to the invention is selected from the group consisting of bovine viral diarrhea virus (BVDV), Type I or Type II, swine fever virus (SFV) and border disease virus (BDV). The complete genome sequence of BVDV (Genebank : NC_001461), SVF (Genbank : NC_002657) and BDV (Genbank : NC_003679) is shown in SEQ ID No 1, 7 and 13, respectively.

The term "*variant*" refers to the homologous polynucleotide sequences and corresponding amino acid sequences found in the different pestivirus strains owing to pestivirus hypervariability.

The term "*pestivirus-like particles*" as used herein refers to non naturally occurring viral particles that comprise an envelope protein of an pestivirus.

The pestivirus pseudo-particles of the invention are infectious for a target cell. The particles of the invention more particularly comprise retroviral core proteins. Such particles may be readily produced by one skilled in genetic engineering techniques. One can for instance refer to EP 1 201 750 that describes production of

synthetic retroviral particles expressing an antigen for modulating an immune response.

In the context of the invention, the term "*infectious*" is used to describe the capacity of the particles of the invention to complete the initial steps of viral cycle that lead to cell entry. However, upon interaction with the host cell, pestivirus-like particles may or may not produce progeny viruses.

The term "*an envelope protein of a pestivirus*" denotes the native Erns, E1 or E2 glycoprotein of a pestivirus, or a mutant thereof.

By an "*Erns glycoprotein*" or "*Erns protein*" is meant a Erns from any specie, genotype, subtype, or variant of perstivirus strains. The amino acid sequence of BVDV, SFV and BDV Erns protein is shown in SEQ ID No 3, 9, and 15, respectively.

By an "*E1 glycoprotein*" or "*E1 protein*" is meant a envelope 1 protein (E1) from any specie, genotype, subtype, or variant of perstivirus strains. The amino acid sequence of BVDV, SFV and BDV E1 protein is shown in SEQ ID No 4, 10, and 16, respectively.

By an "*E2 glycoprotein*" or "*E2 protein*" is meant a envelope 2 protein (E2) from any specie, genotype, subtype, or variant of perstivirus strains. The amino acid sequence of BVDV, SFV and BDV E2 protein is shown in SEQ ID No 5, 11, and 17, respectively.

By a "*p7 protein*" is meant a native pestivirus p7 protein, or a mutant thereof, from any specie, genotype, subtype, or variant of perstivirus strains. The amino acid sequence of BVDV, SFV and BDV p7 protein is shown in SEQ ID No 6, 12, and 18, respectively.

Preferably, Erns, E1, E2, and p7 glycoproteins are derived from a same pestivirus strain. Preferably said Erns and/or E1 and/or E2 and/or p7 proteins are native pestivirus proteins.

The term "*mutant*" or "*mutation*" is meant for alteration of the DNA sequence that result in a modification of the amino acid sequence of native Erns, E1, E2, or p7 proteins. Such a modification can be for instance the substitution and/or deletion of one or more amino acids. Mutants notably include fragments of native Erns, E1, E2 and p7 proteins. Variants are particular examples of naturally occurring mutants. Mutants are more particularly contemplated as useful for identifying the structural elements of Erns and/or E1 and/or E2 proteins, and optionally p7 protein, necessary for maintaining cell infectivity or for increasing Erns and/or E1 and/or E2 antigenicity

for vaccination purposes. In a preferred embodiment, the mutants encompass E2 glycoproteins wherein hypervariable region I has been deleted, while the particles produced therefrom remain infectious.

The term "*pestivirus core*" is meant for a native core protein of a pestivirus strains, a fragment thereof, or a variant thereof from any specie, genotype, subtype, or variant of perstivirus strains. According to an embodiment, the core protein is a N-terminally truncated form of pestivirus core (ΔC) that comprises the core signal peptide. The amino acid sequence of BVDV, SFV and BDV core protein is shown in SEQ ID No 2, 8, and 14, respectively.

Upon completion of its addressing function, the core protein is processed by a cellular protease and thereby cleaved from the pestivirus polyprotein. Accordingly, the pestivirus core protein is not found in the pseudo-particles according to the invention.

The term "*polyprotein*" as used herein is used to describe a protein construct made up of individual proteins that are joined together in a sequence whereby they retain their original relevant biological activities.

The term "*a polyprotein comprising a pestivirus core protein linked to pestivirus Erns and/or a pestivirus E1 protein and/or pestivirus E2 protein*", or "*a polyprotein comprising successively a pestivirus core protein, and a pestivirus Erns and/or a pestivirus E1 protein and/or pestivirus E2 protein*", includes the CErnsE1E2, CE2ErnsE1, CErnsE1, CE1E2, CE2E1, CE1, CE2, ΔCErnsE1E2, ΔCE2ErnsE1, ΔCErnsE1, ΔCE1E2, ΔCE2E1, ΔCE1, and ΔCE2 polyproteins.

Optionally, said polyprotein further contain the p7 protein. The polyprotein comprising a pestivirus core protein linked to pestivirus Erns and/or E1 protein and/or pestivirus E2 protein thus additionally includes the CErnsE1E2p7, CE2ErnsE1p7, CE2p7ErnsE1, CErnsE1p7, CE1E2p7, CE2p7E1, CE2E1p7, CE1p7, CE2p7, ΔCErnsE1E2p7, ΔCE2ErnsE1p7, ΔCE2p7ErnsE1, ΔCErnsE1p7, ΔCE1E2p7, ΔCE2E1p7, ΔCE2p7E1, ΔCE1p7, and ΔCE2p7 polyproteins.

"*CErnsE1E2*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein and a pestivirus E2 protein. "*CE2ErnsE1*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, a pestivirus Erns protein and a pestivirus E1 protein. "*CErnsE1*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus Erns protein, and a pestivirus E1 protein. "*CE1E2*" denotes a polyprotein

comprising successively a pestivirus core protein, a pestivirus E1 protein and a pestivirus E2 protein. "*CE2E1*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein and a pestivirus E1 protein. "*CE1E2*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E1 protein and a pestivirus E2 protein. "*CE1*" denotes a polyprotein comprising a pestivirus core protein linked to a pestivirus E1 protein. "*CE2*" denotes a polyprotein comprising a pestivirus core protein linked to a pestivirus E2 protein.

"*ΔCEmsE1E2*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein and a pestivirus E2 protein. "*ΔCE2EmsE1*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, a pestivirus Erns protein and a pestivirus E1 protein. "*ΔCEmsE1*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus Erns protein, and a pestivirus E1 protein. "*ΔCE1E2*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, and pestivirus E1 and pestivirus E2 proteins. "*ΔCE2E1*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, and pestivirus E2 and pestivirus E1 proteins. "*ΔCE1*" denotes a polyprotein comprising a carboxy terminus of pestivirus core protein linked to a pestivirus E1 protein. "*ΔCE2*" denotes a polyprotein comprising a carboxy terminus of pestivirus core protein linked to a pestivirus E2 protein. *ΔCEmsE1E2*, *ΔCE1E2*, as well as *ΔCE2*, have been built by inserting a stop codon at the end of E2, whereas *ΔCE2EmsE1*, *ΔCEmsE1*, *ΔCE1* , *ΔCE2E1* have been built by inserting a stop codon at the end of E1.

"*CEmsE1E2p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein, a pestivirus E2 protein, and a pestivirus p7 protein. "*CE2EmsE1p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, a pestivirus Erns protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*CE2p7EmsE1*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, a pestivirus p7 protein, a pestivirus Erns protein, and a pestivirus E1 protein. "*CEmsE1p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*CE1E2p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E1 protein, a pestivirus E2 protein, and a pestivirus p7 protein.

"*CE2p7E1*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, a pestivirus p7 protein, and a pestivirus E2 protein. "*CE2E1p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, a pestivirus E2 protein, and a pestivirus p7 protein. "*CE1p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*CE2p7*" denotes a polyprotein comprising successively a pestivirus core protein, a pestivirus E2 protein, and a pestivirus p7 protein.

"*ΔCEmsE1E2p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein a pestivirus E2 protein, and a pestivirus p7 protein. "*ΔCE2EmsE1p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, a pestivirus Erns protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*ΔCE2p7EmsE1*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, a pestivirus p7 protein, a pestivirus Erns protein, and a pestivirus E1 protein. "*ΔCEmsE1p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus Erns protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*ΔCE1E2p7*" denotes a polyprotein comprising a carboxy terminus of pestivirus core protein, a pestivirus E1 protein, a pestivirus E2 protein, and a pestivirus p7 protein. "*ΔCE2E1p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, a pestivirus E1 protein, and a pestivirus p7 protein. "*ΔCE2p7E1*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, a pestivirus p7 protein, and a pestivirus E1 protein. "*ΔCE1p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E1 protein, and a p7 protein. "*ΔCE2p7*" denotes a polyprotein comprising successively a carboxy terminus of pestivirus core protein, a pestivirus E2 protein, and a p7 protein. *ΔCEmsE1E2p7, ΔCE2EmsE1p7, ΔCEmsE1p7, ΔCE1E2p7, ΔCE2E1p7,* ΔCE1p7as well as *ΔCE2p7*, have been built by inserting a stop codon at the end of p7 whereas *ΔCE2p7EmsE1, and ΔCE2p7E1* have been built by inserting a stop codon at the end of E1.

By "*retrovirus*" is meant a virus whose genome consists of a RNA molecule and that comprises a reverse-transcriptase, *i.e.* a member of the Retroviridae family.

Retroviruses are divided into Oncovirus, Lentivirus and Spumavirus. Preferably said retrovirus is an oncovirus, *e.g.* MLV, ALV, RSV, or MPMV, a lentivirus, *e.g.* HIV-1, HIV-2, SIV, EIAV, or CAEV, or a spumavirus such as HFV. Genomes of these retroviruses are readily available in databanks.

In the context of the invention "*a nucleic sequence comprising a packaging competent retrovirus-derived genome*" is intended for a sequence that comprises the retroviral nucleic acid sequences known as "cis-acting" sequences. These include the Long Terminal Repeats (LTRs) for the control of transcription and integration, the psi sequence necessary for encapsidation, and the Primer Binding site (PBS) and polypurine track (PPT) sequences necessary for reverse transcription of the retroviral genome. Advantageously, said nucleic acid sequence comprising a packaging competent retrovirus-derived genome further comprises a transgene.

Said retroviral genome may be replication-defective or replication-competent, in the absence of any trans-complementing function. A replication-competent genome would further comprise the gag, pol, and env retroviral genes. In a replication-defective genome, the viral genes gag, pol, and env are deleted. However, assembly of viral pseudo-particles may be achieved by providing another vector that comprises gag, pol and env but that is defective for the "cis" sequences. Their expression allows the encapsidation of the transgene, excluding the genes necessary for the multiplication of the viral genome and for the formation of complete viral particles.

As used herein, the term "*transgene*" designates the gene that is expressed in the target cell upon infection by the particles of the invention.

Examples of transgenes include a gene encoding a molecule of therapeutic interest, a marker gene, a gene coding for an immune modulator, an antigen, or a suicide gene.

A "*marker gene*" denotes a gene whose expression is detectable. For instance marker gene expression can generate a detectable signal, such as a fluorescence emission, a chromogenic reaction, or confer a growth advantage to the cells wherein it is expressed (antibiotic resistance genes).

An "*immune modulator*" refers to the product of a gene that modifies the activity of the immune system of a subject *in vivo*. Examples of immune modulators include cytokines, (*e.g.* interleukins, interferons, or haematopoietic colony stimulating factors), chemokines, and the like. Expression of an immune modulator by

transformed cells may change the cellular environment and alter differentiation of immune cells and thus modify the type and the strength of immune response elicited against a given antigen.

An "*antigen*" refers to a molecule, such as a peptide, a polypeptide or a protein, against which an immune response is sought. Said antigen may be for instance a tumor, a bacterial, a pathogenic, a proteic, or a viral antigen.

A "*suicide gene*" is meant for a gene whose expression in cells induces programmed-cell death (apoptosis) such as the conditional Herpes Simplex virus type I thymidine kinase gene.

The "*core protein from a retrovirus*" refers to proteins encoded by the gag and pol genes. The gag gene encodes a polyprotein which is further processed by the retroviral protease into structural proteins that comprise the core. The pol gene encodes the retroviral protease, reverse-transcriptase, and integrase.

A "*pharmaceutically acceptable carrier*" refers to any vehicle wherein the vaccine composition according to the invention may be formulated. It includes a saline solution such as phosphate buffer saline. In general, a diluent or carrier is selected on the basis of the mode and route of administration, and standard pharmaceutical practice.

In the context of the present application, "*vaccination*" is intended for prophylactic or therapeutical vaccination. "*Therapeutical vaccination*" is meant for vaccination of a patient with a pestivirus infection.

According to the invention, the term "*subject*" or "*patient*" is meant for any mammal likely to be infected with pestivirus. Cattle, sheep, pigs and goats are examples of hosts for pestiviruses,

Production of pestivirus pseudo- particles

The inventors have generated infectious pseudo-particles that contain functional, and more particularly unmodified, pestivirus glycoproteins assembled onto retroviral core particles. Pestivirus ErnsE1E2, and optionally p7, are expressed from a polyprotein containing the core (C) protein or a fragment thereof, in particular the carboxy-terminus of the C protein, which served as signal peptide for Erns and/or E1 and/or E2 glycoproteins.

The invention thus provides a method for producing pestivirus-like particles *ex vivo* comprising the steps of:

- providing a first nucleic acid sequence comprising a packaging competent retrovirus-derived genome;

- providing a second nucleic acid sequence comprising a cDNA encoding the core proteins from said retrovirus;

- providing a third nucleic acid sequence comprising a cDNA encoding a polyprotein comprising successively a pestivirus core protein, and a pestivirus Erns and/or a pestivirus E1 protein and/or a pestivirus E2 protein;

- transfecting host cells with said nucleic acid sequences and maintaining the transfected cells in culture for sufficient time to allow expression of the cDNAs to produce structural proteins from pestivirus and retrovirus; and allowing the structural proteins to form virus-like particles.

The invention further provides a method for producing pestivirus-like particles *in vivo*, which method comprises the steps of :

- providing a first nucleic acid sequence comprising a packaging competent retrovirus-derived genome;

- providing a second nucleic acid sequence comprising a cDNA encoding the core proteins from said retrovirus;

- providing a third nucleic acid sequence comprising a cDNA encoding a polyprotein comprising successively a pestivirus core protein, and a pestivirus Erns and/or a pestivirus E1 protein and/or a pestivirus E2 protein;

- transfecting cells of a subject *in vivo* with said nucleic acid sequences, to allow expression of the cDNAs to produce structural proteins from pestivirus and retrovirus; and to allow the structural proteins to form virus-like particles.

Another aspect of the invention is the use of three nucleic acid sequences for the preparation of a medicament useful as a vaccine against an pestivirus infection wherein the nucleic acid sequences are :

- a first nucleic acid sequence comprising a packaging competent retroviral-derived genome;

- a second nucleic acid sequence comprising a cDNA encoding core proteins from said retrovirus;

- a third nucleic acid sequence comprising a cDNA encoding a polyprotein comprising successively a pestivirus core protein, and a pestivirus Erns and/or a pestivirus E1 protein and/or a pestivirus E2 protein ;

and, when transferred into cells of a subject, the nucleic acid sequences allow the production of structural proteins from pestivirus and retrovirus, wherein the structural proteins form virus-like particles that are immunogenic.

For the purpose of transfection, said first, second and third nucleic acid sequences may be carried on a same vector, or on two or three separated vectors.

In particular, plasmoviruses, adenoretroviruses and replicating pseudo-viruses are examples of vectors suitable for carrying the above-mentioned sequences. A plasmovirus vaccine consists in such a plasmid DNA preparation, that allow expression of pestivirus pseudo-particles after administration in an patient in order to elicit a immune response against said pestivirus. Administration of such a plasmovirus vaccine being achieved for preventive vaccination into people at risk for pestivirus-induced disease or for therapeutic vaccination into pestivirus-infected patients. Adenoretroviruses consist in an alternative way to provide the above-mentioned nucleic acid sequences encoding pestivirus pseudo-particles. In this case, it is possible to design three independent adenoretroviruses, *i.e.* recombinant adenoviruses, that encode the three nucleic acid sequences mentioned above (retroviral core and genome and pestivirus glycoproteins), or, alternatively, it is also possible to design a single adenoretrovirus, derived from "guttless" recombinant adenoviruses, that contains the different nucleic acid sequences. Such adenoretroviruses can be administered to patient as for plasmoviruses, in order to elicit an anti-pestivirus immune response. Replicating pseudo-retroviruses are another alternative possibility to express all the above-mentioned nucleic acid sequences encoding the pestivirus pseudo-particles. Such structures are in fact pestivirus-pseudo-particles whose genome is engineered to allow, following infection, its propagation into cells of an inoculated patient, thereby inducing the production of further replicating pestivirus pseudo-particles. In this case the genome of a retrovirus is modified so as to express the pestivirus E1E2 glycoproteins in place of the retroviral Env gene (encoding the retroviral glycoproteins). The genes encoding the retroviral core proteins are left unchanged. Futhermore an additional gene, encoding a marker gene or an immunomodulator, for example, can be expressed from this genome.

According to a specific embodiment, said packaging competent retroviral genome and core proteins are derived from a retrovirus selected from the group consisting of MLV, ALV, RSV, MPMV, HIV-1, HIV-2, SIV, EIAV, CAEV, and HFV.

Advantageously, the packaging competent retroviral genome further comprises a marker gene or an immune modulator.

In the method of the invention, said polyprotein may comprise CErnsE1E2, CE2ErnsE1, CErnsE1, CE1E2, CE2E1, CE1, CE2, ΔCErnsE1E2, ΔCE2ErnsE1, ΔCErnsE1, ΔCE1E2, ΔCE2E1, ΔCE1, or ΔCE2 polyproteins.

Preferably, said third nucleic acid sequence comprises a cDNA encoding a polyprotein that further comprises a pestivirus p7 protein. Thus, preferably said polyprotein comprises successively a pestivirus core protein, and a pestivirus Erns protein and/or a pestivirus E1 protein and/or a pestivirus E2 protein, and optionally a pestivirus p7 protein. The polyprotein comprising a pestivirus core protein linked to pestivirus Erns and/or E1 protein and/or pestivirus E2 protein thus additionally comprises the CErnsE1E2p7, CE2ErnsE1p7, CE2p7ErnsE1, CErnsE1p7, CE1E2p7, CE2E1p7, CE2p7E1, CE1p7, CE2p7, ΔCErnsE1E2p7, ΔCE2ErnsE1p7, ΔCE2p7ErnsE1, ΔCErnsE1p7, ΔCE1E2p7, CE2E1p7, CE2p7E1, ΔCE1p7, and ΔCE2p7 polyproteins.

According to an embodiment, Erns and/or E1 and/or E2, and optionally p7 protein, are native proteins. According to another embodiment, Erns and/or E1 and/or E2 proteins, and optionally p7 protein, are mutated to obtain particles that are useful for characterizing the glycoprotein determinants for pestivirus infectivity.

Preferably, said Erns, E1, E2, and optionally p7proteins are derived from a same pestivirus strain.

According to another embodiment said pestivirus core protein is a carboxy terminus form (ΔC) of pestivirus core protein that comprises the core protein signal peptide .

Preferably said pestivirus is selected from the group consisting of bovine viral diarrhea virus (BVDV), swine fever virus (SFV), and Border disease virus (BDV).

In accordance with the present invention there may be employed conventional molecular biology, microbiology, and recombinant DNA techniques within the skill of the art. Such techniques are explained fully in the literature. See, *e.g.*, Sambrook et *al.*, 1989 ; DNA Cloning: A Practical Approach, Volumes I and II (D.N. Glover ed. 1985) ; Oligonucleotide Synthesis (M.J. Gait ed. 1984) ; Nucleic Acid Hybridization [B.D. Hames & S.J. Higgins eds. (1985)] ; Transcription and Translation [B.D. Hames & S.J. Higgins, eds. (1984)] ; Animal Cell Culture [R.I. Freshney, ed. (1986)] ;

Immobilized Cells and Enzymes [IRL Press, (1986)] ; B. Perbal, A Practical Guide To Molecular Cloning (1984) ; F.M. Ausubel et *al.*, 1994.

In particular, the vectors of the invention may be introduced into the target cell by means of any technique known for the delivery of nucleic acids to the nucleus of cells, either in culture, *ex vivo*, or *in vivo*.

Introduction of the nucleic acid sequences may be performed by any standard method well known by one skilled in the art, *e.g.* transfection, electroporation, microinjection, transduction, cell fusion, DEAE dextran, calcium phosphate precipitation, or use of a gene gun (see for instance Wu et al., 1992 ; Wu et al, 1988).

The donor nucleic acid targeting system can also be introduced by lipofection. In certain embodiments, the use of liposomes and/or nanoparticles is contemplated for the introduction of the donor nucleic acid targeting system into host cells. Nanocapsules can generally entrap compounds in a stable and reproducible way. Ultrafine particles (sized around 0.1 µm) that can be designed using biodegradable polyalkyl-cyanoacrylate polymers are contemplated for use in the present invention, and such particles may be are easily made.

Liposomes are formed from phospholipids that are dispersed in an aqueous medium and spontaneously form multilamellar concentric bilayer vesicles (also termed multilamellar vesicles (MLVs)). MLVs generally have diameters of from 25 nm to 4 µm. Sonication of MLVs results in the formation of small unilamellar vesicles (SUVs) with diameters in the range of 200 to 500 Å, containing an aqueous solution in the core. The use of cationic lipids may promote encapsulation of negatively charged nucleic acids, and also promote fusion with negatively charged cell membranes (Felgner et al., 1989).

In vivo targeted gene delivery is described in international patent publication WO 95/28 494. Alternatively, the vector can be introduced *in vivo* by lipofection, using liposomes or nanoparticles as above described. It is also possible to introduce the vector *in vivo* using techniques that are similar to the techniques that are employed *in vitro* (*e.g.* transfection, electroporation...).

Transformed cells

The invention further relates to a transformed host cell that contains :

- a first nucleic acid sequence comprising a packaging competent retrovirus-derived genome;

- a second nucleic acid sequence comprising a cDNA encoding the core proteins from said retrovirus; and

- a third nucleic acid sequence comprising a cDNA encoding a polyprotein comprising successively a pestivirus core protein, and a pestivirus Erns protein and/or a pestivirus E1 protein and/or a pestivirus E2 protein.

Preferably, said third nucleic acid sequence comprises a cDNA encoding a polyprotein that further comprises a pestivirus p7 protein. Thus, preferably said polyprotein comprises successively a pestivirus core protein, a pestivirus Erns protein and/or a pestivirus E1 protein and/or a pestivirus E2 protein, and optionally a pestivirus p7 protein.

Such a transformed host cell is obtainable as described in a method above.

In another aspect, the invention relates to the use of a transformed host cell as defined above, for the identification of molecules capable of interfering with pestivirus entry in cells. The invention provides in particular a method of *ex vivo* screening or identification of molecules capable of interfering with pestivirus entry in cells comprising comparison of the level of transformed host cell fusion to a target host cell, in the presence or the absence of a candidate molecule. Said method preferably comprises the steps consisting of:

- co-culturing a transformed host cell with a target host cell, in the absence or presence of a candidate molecule, under conditions that allow syncytia formation, *i.e.* cell-cell fusion, and pestivirus-like particle entry in target host cell in the absence of any candidate molecule;

- assessing syncytia formation in the absence and in the presence of said candidate molecule;

- comparing syncytia formation measured in presence of said candidate molecule with syncytia formation measured in absence of any candidate molecule;

- identifying as a molecule capable of interfering with pestivirus entry the candidate molecule for which syncytia formation, as measured in the presence of said molecule, is decreased as compared to syncytia formation measured in the absence of any candidate molecule.

Contacting a transformed host cell with a target host cell, and a candidate molecule can be carried out by contacting simultaneously said transformed host cell,

target host cell and candidate molecule. Otherwise, two of these three elements can be contacted under conditions sufficient to allow their interaction before addition of the third missing element.

Preferably said target host cell is not transformed, *i.e.* said target host cell does not contains at least one of the first, second, and third nucleic acid sequence as defined above.

Syncytia formation can be readily assessed by one skilled in the art. Briefly, the coculture is submitted to a acidic pH drop by incubation for 5 min at pH-5 and incubated in a nomal medium for an additional 12 hrs. Cultures are then stained by adding the May-Grunwald and Giemsa solutions (MERCK) according to the manufacturer recommendations. Cells containing two or more nuclei can be defined as syncytia. A fusion index is then defined as the percentage of (N-S)/T where N is the number of nuclei in the syncytia, S is the number of syncytia and T is the total number of nuclei counted.

Pestivirus-like particles

In the method described above no structural modifications of the E1E2 glycoproteins are required for their correct assembly on retroviral cores. The method of the invention thus makes it possible to generate high titre infectious pestivirus pseudo-particles with functional E1E2 proteins. As demonstrated herein, these particles constitute a valid model of pestivirus virions as regards to early steps of viral infection cycle.

The invention further relates to an infectious pestivirus-like particle, comprising the core proteins from a retrovirus, and Erns and/or E1 and/or E2 pestivirus glycoprotein(s), and optionally p7 protein. Such a particle is obtainable by a method as described above.

According to an embodiment, the infectious particle of the invention may comprise native pestivirus E1 protein, or native pestivirus E2 protein, or native pestivirus Erns protein and native pestivirus E1 protein, or native pestivirus E1 protein and native pestivirus E2 protein, or native pestivirus Erns protein and native pestivirus E1 protein and native pestivirus E2 protein. Preferably said Erns and E1, or E1 and E2, or Erns, E1 and E2 proteins are derived from a same pestivirus strain. According to another embodiment, Erns and/or E1 and/or E2 glycoproteins are mutated.

Preferably the above described infectious particle of the invention further comprise a native pestivirus p7 protein. Preferably, said E1 and E2 glycoproteins, and p7 protein are derived from a same pestivirus strain. Still preferably said Erns, E1 and E2 glycoproteins, and p7 protein are derived from a same pestivirus strain According to another embodiment, Erns and/or E1 and/or E2 glycoproteins and/or p7 protein are mutated.

Preferably said pestivirus is selected from the group consisting of bovine viral diarrhea virus (BVDV), swine fever virus (SFV), and Border disease virus (BDV).

Said retrovirus may be selected from the group consisting of MLV, ALV, RSV, MPMV, HIV-1, HIV-2, SIV, EIAV, CAEV, and HFV.

Advantageously, said infectious particles further carry a transgene. For instance said transgene may be a marker gene which make it possible to follow-up cell infection by the infectious particles of the invention and can find application for instance in the identification of a cell receptor involved in pestivirus entry. Said transgene can also be a gene encoding a molecule of therapeutic interest and/or a suicide gene.

Use of the infectious pestivirus-like particles of the invention

High infectivity of these particles makes it possible for the investigation of the role of pestivirus Erns, E1 and E2 glycoproteins and their potential receptors in cell entry, pestivirus host-range and neutralisation by antibodies from pestivirus patient sera.

The invention therefore concerns the use of a pestivirus-like infectious particle as described above, for *ex vivo* identification of a cell receptor for pestivirus Erns and/or E1 and/or E2 glycoprotein.

According to an embodiment, the invention provides a method for *ex vivo* identification of a receptor for pestivirus Erns and/or E1 and/or E2 glycoprotein comprising detection of the binding of said particle to a cell receptor. More specifically, the method may comprise the steps consisting of:

- contacting a cell susceptible to pestivirus infection with an infectious pestivirus-like particle of the invention, under conditions sufficient to allow specific binding of said particle to a receptor expressed at the surface of said cell;
- detecting binding of said particle to a receptor; and
- identifying said receptor.

A cell susceptible to a pestivirus infection, may be for instance a kidney primary cell, or cell line, form cattle, pig, or sheep.

Detection of particle binding to a receptor can be achieved according to classical procedures well known by one skilled in the art. For instance, this could involve radioactive, enzyme or fluorescent labelling of the particles of the invention, and subsequent detection with an appropriate method. A number of fluorescent materials are known and can be utilized as labels. These include, for example, fluorescein, rhodamine, auramine, Texas Red. Enzyme labels consist in conjugation of an enzyme to a molecule of interest, *e.g.* a polypeptide, and can be detected by any of colorimetric, spectrophotometric, or fluorospectrophotometric techniques. Flow cytometry analysis (FACS) together with labelled antibodies directed against E1 or E2 proteins harboured by the pseudo-particles of the invention is also appropriate.

According to another embodiment, the invention provides a method for *ex vivo* identifying a cell receptor for a pestivirus comprising the step consisting of:

- transfecting a cell which is not permissive for pestivirus infection with a nucleic acid sequence encoding a protein likely to be a receptor for pestivirus;
- contacting said transformed cell with a pestivirus-like particle of the invention;
- determining whether said transformed cell has become permissive or not for pestivirus infection; and
- identifying as a cell receptor for a pestivirus said protein expressed by the transformed cell that has become permissive.

Determination of whether the transformed cell has become permissive for pestivirus infection can be readily achieved using the pestivirus-like particles of the invention. In particular, where said particles carry a marker gene, such as GFP, permissivity (*i.e.* the capacity of cells to be infected with a pestivirus, or with a pestivirus-like particle) can be assessed by FACS analysis of the transformed cells. Where the marker gene is an antibiotic resistance gene, identification of cells infected by the pestivirus-like particle is readily achieved through exposure to said antibiotic.

Where one does not suspect a given protein to be a receptor for pestivirus entry, in cells, the above method can advantageously be adapted for the screening and the identification of a cell receptor for a pestivirus. In particular, an expression cDNA library can be prepared, for instance from a cDNA library obtained by reverse-transcription of cellular mRNAs from a cell permissive for pestivirus infection. Expression of such a cDNA library would be driven by a constitutive promoter whose

nucleic acid sequence has been fused to the cDNA library in suitable vectors. Such a library would contain a vector encoding a cell receptor for a pestivirus. Non permissive cells can then be transfected with this expression library and further screened for the identification of a cell receptor for a pestivirus.

To this end, the invention proposes a method for *ex vivo* identifying a cell receptor for pestivirus comprising the step consisting of:

- providing an expression cDNA library obtained from a cell permissive for pestivirus infection;
- transfecting cells that are not permissive for pestivirus infection with said expression cDNA library;
- contacting said transformed cells with pestivirus-like particles of the invention;
- identifying and isolating those transformed cells that have become permissive for pestivirus infection;
- isolating the expression vector transfected in cells that have become permissive; and
- identifying as a receptor for pestivirus the proteins encoded by the cDNA sequence of said isolated expression vectors.

Advantageously, the expression cDNA library is expressed from retroviral vectors that comprise glycoproteins that allow infection of the pestivirus non permissive cells. Such glycoproteins can be the VSV-G glycoprotein derived from vesicular stomatitis virus (VSV) whose receptor is expressed in most cell types *ex vivo*. Such viral particles can be assembled using a packaging competent retrovirus-derived genome that comprises the expression cDNA library, and optionally a marker gene. According to this embodiment the method for isolating the expression vector expressed in cells that have become permissive to infection by the pestivirus-like particles of the invention is greatly facilitated. Indeed this latter embodiment is particularly advantageous in that the process of cell infection with retroviral vectors has greater efficacy, as compared to cell transfection. Furthermore, cell infection leads to stable integration of viral genome in the cellular genome. Accordingly, transgenes, *i.e.* cDNA and marker gene that are carried by the pseudo-particles of the invention, are found to be stably expressed by infected cells. This in contrast with classical vectors used for transfection that do not integrate into cellular genome and for which expression may be transient.

In another aspect, the invention relates to the use of an infectious particle as defined above, for the identification of molecules capable of interfering with pestivirus entry in cells.

In particular, herein is provided a method of *ex vivo* screening or identification of molecules capable of interfering with pestivirus entry in cells comprising comparison of the level of cell infection by the particles of the invention in the presence or the absence of a candidate molecule. Said method preferably comprises the steps consisting of:

- contacting a cell susceptible to pestivirus infection with an infectious pestivirus-like particle, in the absence or presence of a candidate molecule, under conditions that allow cell infection with pestivirus-like particle in the absence of any candidate molecule;
- assessing cell infectivity in the absence and in the presence of said candidate molecule;
- comparing cell infectivity measured in presence of said candidate molecule with cell infectivity measured in absence of any candidate molecule;
- identifying as a molecule capable of interfering with pestivirus entry the candidate molecule for which cell infectivity, as measured in the presence of said molecule, is decreased as compared to cell infectivity measured in the absence of any candidate molecule.

Contacting a cell susceptible to pestivirus infection with an infectious pestivirus-like particle, and a candidate molecule can be carried out by contacting simultaneously said cell, pestivirus-like particle and candidate molecule. Otherwise, two of these three elements can be contacted under conditions sufficient to allow their interaction before addition of the third missing element.

Cell infectivity can be readily assessed by one skilled in the art. One can take advantage of the embodiment wherein the infectious pestivirus-like particle carries a detectable marker gene to detect cell infection. In a preferred embodiment, the marker gene is a fluorescent marker gene, such as GFP, and the infection is detected by means of fluorescence measurement, for instance by flow cytometry analysis of cells contacted with said infectious particles.

A cell suitable to be used in the method of identification of molecules interfering with pestivirus cell entry may be for instance a kidney primary cell, or cell line, from cattle, pig or sheep.

Such molecules capable of interfering with pestivirus entry in cells may constitute new antiviral drugs.

The infectious particles of the invention are further useful for diagnosis of pestivirus infection and follow-up of pestivirus infection, for instance to assess efficacy of a therapy in a patient.

The invention thus concerns the use of an infectious pestivirus-like particle for the *in vitro* detection of antibodies directed against pestivirus in a biological sample from a subject susceptible to be infected with pestivirus. Said biological sample may be a biological fluid, such as blood or serum, or a tissue biopsy. In a specific embodiment, said antibodies are directed against Erns and/or E1 and/or E2 pestivirus proteins.

Accordingly, the invention provides a method of *in vitro* diagnosis of a pestivirus infection in a patient comprising detecting immune complexes formed by interaction of anti-pestivirus antibodies likely to be present in a biological sample of the patient, with pestivirus-like particle of the invention. Said method may in particular comprise the steps consisting of:

- contacting a biological sample with an infectious pestivirus-like particle of the invention under conditions sufficient to allow formation of complexes by binding of said infectious particle to antibodies directed against pestivirus present in the biological sample;
- detecting said complexes, which presence is indicative of a pestivirus infection.

The presence of antibodies reactive with pestivirus-like particles can be detected using standard electrophoretic and immunodiagnostic techniques, including immunoassays such as competition, direct reaction, or sandwich type assays. Such assays include, but are not limited to, Western blots; agglutination tests; enzyme-labeled and mediated immunoassays, such as ELISAs; biotin/avidin type assays; radioimmunoassays; immunoelectrophoresis; immunoprecipitation, etc. The reactions generally include revealing labels such as fluorescent, chemiluminescent, radioactive, enzymatic labels or dye molecules, or other methods for detecting the formation of a complex between the pestivirus-like particle and the antibody or antibodies reacted therewith.

In another embodiment, said method of *in vitro* diagnosis of a pestivirus infection in a patient comprises detecting an inhibitory effect of anti-pestivirus antibodies likely to be present in a biological sample of the patient, on the infection of a permissive cell by a pestivirus-like particle of the invention. Said method may in particular comprise the steps consisting of:

-contacting a cell permissive for pestivirus infection with a pestivirus-like particle and a biological sample;

- comparing cell infectivity measured in presence of said biological sample with cell infectivity measured in absence of said biological sample;

- detecting the inhibition of pestivirus-like particle infection of a permissive cell as a decrease in cell infectivity measured in presence of said biological sample compared with cell infectivity measured in absence of said biological sample, said inhibition being indicative of a pestivirus infection.

This embodiment is advantageous in that the method relies on the detection of the specific antibodies that are neutralizing for cell infection, that is those patient's antibodies that are effective against viraemia.

In a further embodiment of this invention, commercial diagnostic kits may be useful to carry out the above diagnosis methods, by detecting the presence or absence of immune complexes formed by pestivirus particles and antibodies directed against pestivirus in a biological sample from a subject susceptible to be infected with pestivirus, or by detecting an inhibition of pestivirus-like particle infection of a permissive cell by anti-pestivirus neutralizing antibodies likely to be present in a biological sample of the patient. Such kits may comprise at least a pestivirus-like particle of the present invention. Where the method involves detection of immune complexes, the kits may further comprise appropriate means of detection of said immune complexes. Preferably the kit of the invention further comprises directions, and protocols, depending upon the method selected, *e.g.*, "competitive", "sandwich", and the like. The kits may also contain peripheral reagents such as buffers, stabilizers, etc...

In another aspect of the invention, the infectious pestivirus-like particles may be used for vaccination purposes.

According to an embodiment, the invention thus proposes a method of vaccination, notably against pestivirus infection, that comprises administration of a

pestivirus-like particle to a subject in need thereof. The invention also relates to a vaccine composition comprising a pestivirus-like particle and a pharmaceutically acceptable carrier. The invention further provides an immunogenic composition comprising in a pharmaceutical acceptable carrier, a pestivirus-like particle disclosed herein.

The vaccine and immunogenic compositions of the invention may be drawn to confer immunity, or elicit an immune response against pestivirus.

However, where the pestivirus-like particles of the invention further carry an additional gene encoding another antigen, different from pestivirus antigens, the invention provides a recombinant viral vaccine useful to raise an immune response against said antigen. Actually, the use of pseudo-particles described herein makes it possible to improve the elicited immune response through combining several presentation and processing pathways of an antigen. For instance, a vaccine composition of the invention, when administered, results in the pestivirus-like particles infecting cells of the host. The transgene encoding the antigen is then integrated in the cellular genome, and subsequently expressed by the cell, such that there is both a cellular and a humoral immune response elicited by the vaccine composition.

Advantageously, the pestivirus-like particles may further carry a transgene encoding an immune modulator, which allows for enhancement of the raised immune reaction.

The vaccination or immunogenic composition of the present invention may additionally contain an adjuvant. A number of adjuvants are known to those skilled in the art. Examples of suitable adjuvants include, for example, include aluminum hydroxide; Saponin; detergents such as Tween 80; animal, mineral or vegetable oils, Corynebacterium or Propionibacterium -derived adjuvants; Mycobacterium bovis (Bacillus Calmette and Guerinn, or BCG); cytokines; acrylic acid polymers such as carbomer; EMA; or combinations thereof.

The route of administration is any conventional route used in the vaccine field. As general guidance, a vaccine composition of the invention is administered via a mucosal surface, *e.g.*, an ocular, intranasal, pulmonary, oral, intestinal, rectal, vaginal, and urinary tract surface; or via a parenteral route, *e.g.*, by an intravenous, subcutaneous, intraperitoneal, intradermal, intraepidermal, or intramuscular route. The choice of administration route depends on the formulation that is selected.

In still another embodiment the particles of the invention may be used as vectors for gene transfer and/or gene therapy. Gene therapy is defined as the introduction of genetic material into a cell in order to either change its phenotype or genotype. Furthermore, such a delivery system is amenable to scale up for reproducibly producing large titers of infectious, replication-defective pestivirus-like particles particles.

Accordingly, the invention relates to a method for *in vivo* or *in vitro* transferring a transgene of interest in a cell, which method comprises infecting a cell with a pestivirus-like particle of the invention, wherein the particle carries a transgene of interest.

The invention further relates to the use of a pestivirus-like particle of the invention, that carries a transgene of interest, for the preparation of a medicament for the prevention or treatment of a disease in a patient, wherein the pestivirus-like particle allows the transfer of the transgene of interest into a cell of the patient, and encodes a product that has a prophylactic or therapeutic effect against the disease.

In the above described uses of the particles of the invention the pestivirus may preferably be selected from the group consisting of bovine viral diarrhea virus (BVDV), swine fever virus (SFV), and Border disease virus (BDV).

The invention will be further understood in view of the following examples.

EXAMPLE 1 : Generation of pestivirus pseudo-particles

Pestivirus pseudo-particles are generated by assembling full-length, unmodified Erns, E1 and E2 glycoproteins onto retroviral core proteins derived from murine leukemia virus (MLV). To investigate further whether functional pestivirus pseudo-particles are also produced with Erns, E1 and E2 expressed in *trans* with only one or two of the glycoproteins, expression vectors that encode Erns, E1, E2, Erns and E1, Erns and E2, or Erns and E1 and E2 glycoproteins are designed.

Construction of expression vectors encoding the viral components

Plasmids expressing wild type ErnsE1E2 polyproteins are constructed by standard methods (Sambrook et *al.*, 1989).

The specific polynucleotide and polypeptide constructs of BVDV deltaCErnsE1E2p7, deltaCErbsE1E2, deltaCE1E2p7 and deltaCE1E2 are shown in SEQ ID No19 to 26, respectively.

Generation of pestivirus pseudo-particles

Retroviruses were chosen as platforms for assembly of pestivirus-pp because their cores can incorporate a variety of different cellular and viral glycoproteins and because they can easily package and integrate genetic markers into host cell DNA.

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